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PROVINCE OF MANITOBA



BETTER ROADS

Principles of Road Construction and Maintenance

DEPARTMENT OF PUBLIC WORKS, HIGHWAY
COMMISSIONER'S OFFICE. WINNIPEG, 1912.

Hon. COLIN H. CAMPBELL,
Minister of Public Work.

CHAS. H. DANCER,
Deputy Minister.

A. MCGILLIVRAY,
Highway Commissioner.



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Importance of Highway Improvement

There is no other work which a municipal council is called upon to undertake, or upon which public funds are expended, that is of more importance or requires more serious and considerate attention than the building and maintaining of the public highways. The benefits, material and social, accruing from a well constructed and properly maintained system of roads, in keeping with the means and requirements of a community are so obvious and distinct, that the best efforts of not only the authorities themselves, but of the ratepayers in general, should be exerted towards instituting comprehensive plans for carrying on their roadwork, so that the best results may be obtained at a minimum outlay, and the ensuing benefits received without unnecessary delay.

It would be well for the different municipal authorities to undertake a reasonable amount of improvement work on their roads at one time with the intention of completing the same within a certain period, say one, two, three or even more years. A general plan could be outlined, embracing the construction or improvement of a certain mileage of roads in a given period. Of course, all the details could not be worked out from the first, as certain changes might have to be made from time to time to meet unforeseen conditions which might arise during the progress of the work, but the authorities would have before them a definite proposition which would enable them to proceed in a practical, businesslike manner and thus avoid a great deal of unnecessary delay, costly expenditures for the repairs and rebuilding of partly, and very often poorly, constructed pieces of work, indiscriminately started here and there throughout a district.

MAIN TRUNK ROADS.

There are in every municipality certain roads which owing to their peculiar location in the district are more travelled than others. They may be termed the main roads. As the traffic from the country approaches towns, villages or shipping points:

on the railways, it is concentrated on certain roads that lead up to these points. Therefore, the conditions on these roads are more exacting than on side roads on account of the increased traffic upon them. It is on these main arteries of transportation that special attention should first be directed, so that their standard may be elevated to a degree of efficiency and serviceableness, consistent with the means and requirements of the municipality.

Tentative plan of procedure. The successful consummation of any undertaking, either great or small, is largely dependent on the system employed in executing its several details. The improvement of the highways of a district is a large and important undertaking, and therefore should be proceeded with in a systematic manner. A proper plan to adopt would include:

- (1) The selection of the roads to be improved at the present time, the location of these roads being so placed that their improvement would benefit the greatest number of the residents of the district and be a general improvement to the community as a whole.
- (2) The securing of the services of an engineer with whose assistance the lines of roads to be improved would be finally located and the following information secured:
 - a. Information with regard to the necessary drainage of the roads. (This is most essential as the life and usefulness of the road depends entirely on its drainage.)
 - b. Preparation of plans and profiles of the roads and drains, with specifications covering the whole work.
 - c. Estimate of cost of proposed work.
- (3) Providing ways and means of securing the necessary funds for carrying on the work to completion.
- (4) Letting of the work by contract—It is generally more satisfactory to have work of this character performed by contract, if it can possibly be arranged, which can generally be done on new work. Sometimes work which consists of re-building, improving old drains or extending the width or height of old roads, can be done more satisfactorily by day labor.
- (5) Appointing a competent man as superintendent or overseer who will see, in cases where work is being done by contract, that the specifications and plans are being strictly adhered to, and where work is being done by day labor that proper organization for executing the work is established and maintained along the strictest lines of economy with a view of attaining the most satisfactory and durable results.

Work should be undertaken on main roads first.

As before mentioned, the roads of most travel should receive first attention. It is impossible, and at present unnecessary, to improve all the roads of a municipality at one time. Road building is a work that will continue for many years, but a proper start should be made somewhere, and it is only reasonable to expect that this should be made upon the roads used the most by the greatest number of the residents.

A start might be made from the marketing points on the lines of railways in the different municipalities and the leading roads running into the country from these points selected for improvement. Care should be taken to see that the roads selected for improvement are so located that they will render the greatest service to the greatest number of residents, and be a lasting benefit to the whole municipality. They might be gravelled, or otherwise provided with a dressing of harder and more durable material than earth; but whether this is done at first or not, a municipality by providing good drainage facilities and constructing suitable grades would be preparing the way for more permanent work in the future.

ENGINEERING ADVICE.

The services of an engineer is essential so that the necessary information with regard to the levels and topography of the country may be obtained and plans for proper drainage established. It is unadvisable to attempt to follow at all times the surveyed lines of sections with drainage ditches. The best possible lines of outfalls for these drains should be ascertained and the drain located thereon. This can only be done in a satisfactory manner by a competent engineer, after he has made the necessary surveys. Present practice in many of the rural municipalities, permits of a great deal too much work being done without having first secured sufficient information concerning the levels and natural topography of the district, and many miles of drains and road grades are constructed without providing adequate outlets for the water, with the consequence that the best results are very seldom obtained or proportionate benefits for the expenditure of money received.

FINANCING HIGHWAY IMPROVEMENTS.

It may be truly said that the lack of money is the greatest obstacle in the way of obtaining better road conditions. Road construction and maintenance cost money and the question of raising a revenue for this purpose is an important one.

Do not take up space with worthless observations

It has frequently occurred that propositions for the improvement of highways, involving the expenditure of certain sums of money, to be levied by a direct tax, bond issue or other method of raising funds, have been submitted to a people and rejected by them. This did not always signify, however, that those people were opposed to good roads, for in many instances it has happened in communities imbued with a strong feeling in favor of better road conditions. The trouble may have been that the people were insufficiently informed on the relative merits of the different methods of raising funds and perhaps, wisely declined to accept any proposition until they became sufficiently acquainted with its general working, or they may have deemed the proposed amount to be a greater financial burden than they were capable of bearing at one time.

It would appear advisable when contemplating a scheme of improvements of this kind to take into consideration several points connected with it. These might be as follows:—The particular highways upon which the improvements were to be made, the nature and extent of such improvements, the estimated cost of carrying the work to completion, the method of collecting sufficient revenue to meet this expenditure, and the financial ability of the community to assume the estimated liability. There is no doubt, a proper representation of the whole matter should be put before the people that it might be thoroughly understood by them before asking them to decide upon it. Meetings should be held at which all phases of the question would be discussed and the taxpayer enlightened on the proposed expenditures and the benefits and results which are expected to accrue. Road improvement is simply a business proposition and as such should be dealt with along business lines. No private company or corporation would think of launching into a scheme of extensive improvements in its business without deliberation or reflection. What is required in all business undertakings is organization, and road building is no exception to this rule. Systematic organization is just as necessary in its initial stages as it is in the final execution of any plan that may be adopted.

There are many methods of procuring revenue for the improvement of the highways. Among these may be mentioned statute labor, direct taxation and bond issues.

Statute labor. The system of statute labor which has been in vogue in this country since the formation of the first municipality, permits the payment of road taxes at the option of the

taxpayer in labor instead of cash. There has been a large amount of criticism of this system in late years, many of the counties of Ontario and a few of the municipalities of this province having entirely abolished it. So far as the system itself is concerned, there does not appear to be very much that can be said against it. Road improvement is almost entirely a matter of labor and its direction. It is the abuse of the system that has thrown it into such bad repute in the minds of so many. Many men who work out their road taxes do so without the least feeling of responsibility; their only object being to relieve themselves of their obligation in the easiest manner possible. If every man would give the same honest day's work in the performance of statute labor as he would be compelled to do if working for a private corporation, there is no gainsaying the fact that it would be possible to accomplish a great deal of good in the way of road maintenance and improvement. It might be said in defence of the system that a road commissioner or pathmaster who would be unable to exact a proper day's work from a man performing his duties of statute labor, would be equally unable to secure a just proportion of labor from the same man for any stipulated wage; so that in cases where the working out of the system fails to satisfy the ends which it is intended it should, the fault does not rest altogether with the system, but in most instances with the manner in which it is carried out.

On the other hand, the principle upon which this system is carried out divides the municipality into numerous small road districts, in which the management of the work is assigned to pathmasters, who have full control of the labor and the manner in which it shall be performed in their respective districts. This tends to disrupt the idea of uniformity of construction in the municipality and with the continual change of pathmasters, prevents to a large extent the continuity or uniformity of work even in a unit district, because it will seldom be found that a pathmaster will follow out the ideas and work initiated by his predecessors. If all the road work of a municipality was put under the supervision of a competent man, who would not hesitate to demand a fair day's work, and who would see that the proper methods of carrying on this class of work was put into effect, there would soon be a vast difference, not only in the kind of work performed, but also in the amount that would be done each year.

Direct taxation. The system of direct taxation has been practised considerably more in this province for securing a revenue for road improvement than the system of bond issues. A large number of people favor it on account of it being a "pay as you go" plan, being averse to any system that will establish an indebtedness on a community for a term of years. Whatever may be said in justification of this plan, it must be admitted, however, that in a new and undeveloped country the burden on the present ratepayer would be more than he could bear if the progress within that country is to keep pace with the requirements for urgent and necessary improvements. It would be well to adhere to such a "pay as you go" system in a community with an assessed valuation of sufficient magnitude to produce an adequate annual revenue for the requisite improvements therein without imposing a hardship on the people, but in a district where the amount which can be raised yearly is necessarily limited, the delay in producing any material results will be so great that the benefits accruing therefrom will be very small indeed for some time.

Bond issues. The chief advantage of bond issues is that a large amount of capital can be obtained immediately. Improvements having been mapped out by the authorities, can be pushed to completion with reasonable dispatch, say in two or three years, and the ensuing benefits enjoyed much earlier by those who are assuming a share of the burden of paying for them. Moreover, a portion of the burden would be lifted from the shoulders of the present taxpayers and from present property values and placed upon the future generation, and increased property values largely resulting from these improvements.

It might also be said that with sufficient funds to carry on an extensive plan of improvements, the work can be done more cheaply. Contractors would be willing to equip themselves more fully with modern plant to engage in this line of business. This is something that should be encouraged as much as possible by municipal authorities, as the scarcity of well equipped outfits for this class of work is a serious retardment in the developing of better road conditions in this province. There is at present insufficient work of this nature going on in one locality to warrant a reasonably large outlay for equipments of this sort, and for this reason road improvement is often seriously hampered.

Proceeds of The revenues from bond issues for road purposes
Bond issues should be restricted to the construction of new
should be work entirely. Funds raised by this means should
used for not be devoted to maintenance. While in con-
construction sidering a proposition for improvements, it is es-
work only. sential to keep in view the great necessity of future maintenance
—because no road should be built and then permitted to deteri-
orate through lack of attention, and no road can be built that
will not require some attention for repairs—yet it would be un-
advisable to procure a revenue for this purpose from a bond issue.
The funds should be procured by a direct tax levied annually
and devoted to the keeping of these highways in proper state
of repair.

A proposition for raising money for highway improvement
should be considered by every taxpayer from a business stand-
point, and if looked upon in that light, there would be no reason
to fear an over-indebtedness on a community. The roads are for
public use and a public benefit, and the judicious expenditure of
public funds for bettering the roads is an investment in which
every municipality can afford to engage.

ROAD MANAGEMENT.

Road construction is almost altogether a matter of labor
and its direction. The cost of gravel or broken stone or other
road material is very small indeed compared with the cost of
delivering it on the roads, spreading and otherwise preparing
it for traffic. The excavating of drains is entirely a question
of labor. Such being the case, it is very important, indeed, if
work is to be performed in the most economical and efficient
manner, that a reliable and competent man who will see that
value is received for every dollar of expenditure, be placed in
charge thereof.

See p

An experienced man will be able to get better results from
the efforts of his men and teams, in being familiar with the nature
of the work, in knowing how to arrange his gangs so that each
man will have his place on the work and so that there will be
no overcrowding. He will have a proportionate number of men
to handle properly the number of teams engaged, thus preventing
delays and permitting the work to proceed smoothly. He will
be able to fix the size and number of loads which shall constitute
a day's work, and to see that his men and teams put in the
required number of hours each day.

No "rule of thumb" principle can be laid down for the proper construction of roads. Each individual portion will require consideration and specific treatment, for, not only is the first cost of the work affected by the manner in which it is performed, but the life and serviceableness of the road itself are dependent upon the care and attention given to its first construction. In short, the future usefulness and cost of maintenance of a road must depend almost entirely upon the effectiveness of the work put into the drainage and building of the sub-grade.

Municipal councillors, upon whom, under the present method of dealing with road work, the direct charge of seeing that it is properly done, cannot as a rule devote sufficient time to conduct it as it should be done, and must depend largely on the integrity and ability of whomsoever they can find at the time who are willing to undertake the handling of the work for them. It cannot be expected that the best results will ever be obtained in this way, or the greatest amount of work received for the money expended.

The building of roads is a work which responds amazingly to good organization. With efficient management and organization, the returns for the energy and money now being expended from year to year by the different municipalities—although in many places inadequate—could be greatly increased. The practice so prevalent of dividing the yearly appropriations into ward allotments and again sub-dividing the allotments into numerous small sums for expenditure here and there throughout the wards, would tend to disrupt the best organization that might be instituted. These small sums are in many cases so insignificant and inadequate that before a road superintendent could get his work properly started or fairly under way the amount is exhausted, necessitating the leaving of that portion in probably a very unfinished state, and resuming work in some other part with possibly the same results and experience.

In order to obtain the best results from efficient organization, a reasonable amount of work must be undertaken, and there are in every municipality certain improvements in road building which might be undertaken advisedly, that would immediately prove of immense benefit to the community, and if proceeded with on a comprehensive scale would permit of a general scheme of organization being established and followed out, whereby not only a great saving would be made in the cost of doing the work, but more effective work could also be done.

THE EARTH ROAD.

The scarcity in many parts of this province of gravel, stone or other suitable material for the surfacing or construction of what may be termed hard roads, will no doubt necessitate the use of the common earth roads as the avenues of transportation in many of our rural districts for some time to come. Again, when considering the great mileage of roads that are now and will, in increasing proportions, be so necessary for the development of this country, it must be admitted that the enormous cost of their construction and maintenance will preclude for some time yet the building of any more than a small percentage of the higher standard of roads, so it becomes very apparent that the importance of the earth roads cannot be overestimated, and they should receive due care and consideration with regard to their construction if the country is to receive that quota of advantage that their existence should imply. There is no doubt but that the efficiency of the earth road can be increased and its usefulness prolonged by the adoption of proper methods of construction and judicious systems of maintenance.

Drainage. Water is the greatest enemy and destroyer of the earth road and drainage the only remedy for this evil. It is impossible to construct an earth road, or in fact any road, without giving due attention to its drainage. The importance of drainage has been emphasized in the statement that the "three prime essentials to good roads are: First, drainage; second, better drainage; and third, the best drainage possible." By drainage is meant that provisions be made for the escape of the water from the foundation of the road and the cross section of the grade so shaped by giving it sufficient crown that water will not be permitted to lie upon its surface, but shall have free access to the side ditches.

Open Drains It will generally suffice, in providing drainage for the foundation of a road, to construct open drains along the sides of the grade. These drains must be made continuous to free outlets and be of such a size that they will carry adequately all the water collected in them, during freshets or wet seasons. It is simply useless to construct trenches along the side of the road without connecting them with existing offtakes or outlets. Unless provisions are made for the escape of the water from these trenches they will merely serve as receptacles for holding the water until such times as it evaporates or is absorbed by the soil to the injury of the foundation of the road, which would

be kept in a soft, wet condition, instead of being permitted to become dry and consolidated, and thus enabled to properly sustain the weight of the traffic imposed upon it. These stagnant pools are unsightly and not only a source of great injury to the foundation of the road, insomuch that they keep the soil soft and wet for an undue length of time, but they are also a menace to the safety of travel.

Foundation. Upon the foundation depends entirely the success, durability and serviceableness of the road, and an endeavor should be made at the inception of the work to eliminate as far as possible anything that may tend to weaken the foundation. It is a great waste of money to build up earth grades without providing for the drainage of the soil upon which these are placed, because if the soil is wet the grades will disappear in a very short time and the condition of the road become as bad if not worse than ever.

Side Drains. The size of the drains along a road will depend largely on the conditions of the surrounding country as the amount of water that will be tributary to them and the natural inclination along their course will have to be considered in laying them out. They should have at the very least a minimum depth of twelve inches so as to allow for sufficient drainage for the foundation of the road across the lower lying lands, where for natural reasons the soil will be the wettest and in reality require the exercise of special precaution with regard to its drainage. The functions of these drains may be said to be twofold. Besides being channels for discharging the surface water, that may be collected in them from the surrounding district, into the larger outlets or natural waterways of the country, they also provide for the drainage of the soil contiguous to their course for some depth below its natural surface and for a certain distance from the sides of the drain. The extent to which the soil will be affected in this way, depends

Drains should have a minimum depth of 1' across lower lying lands.

Tile drains necessary to procure best results in heavy or springy soil.

upon the depth of the drain and the natural characteristics of the soil itself. If the soil is light and contains natural drainage facilities, the desired results can be obtained through open drains, but if it is springy and of a heavy retentive nature, tile drainage must be resorted to, if the best results are to be procured.

Width of ditches. The ditches along a road should be made sufficiently large to enable them to carry away quickly all the water tributary to them, and as the fall of the ditch governs to a great extent its capacity for discharging water, the width and depth will depend on the amount of fall obtainable along its course.

Where more material is required for building a suitable earth road than can be had from ditches which may be sufficiently large for drainage purposes, it should be obtained by extending the width of the ditch, rather than by increasing its depth. In securing a continuous and uninterrupted flow for the water, the drains will naturally have to possess a greater depth through the ridges or higher ground than through the lower lying lands along its course. Consequently there will be more material to be excavated through the higher ground where it is not required for a road dump, than through the lower levels where a higher dump is required. The proper method to follow in such cases is to use the material excavated from the ridges, in supplementing that taken from the shallower drains through the lower levels and in this way make up a suitable embankment over these low places. The practice to be avoided is that of excavating from the bottom of the ditches below the levels established for drainage purposes, whereby elongated ponds from which water cannot escape will be left in the bottom of the drains. Water collected in these holes is sure to affect the stability of the road foundation

Material should be hauled from ridges to make up embankments across low ground.

The deficiency in the quantity of material for a proper road grade should be supplied by hauling it from nearby ridges where these are situated at reasonable distances from where the material is needed, or in the event of the haul from such places being so long that the cost of moving the material may be considered excessive, then the embankment should be made up by extending the width of the ditches contiguous to it, always preserving the levels of the bottom of the ditch established for drainage.

No definite rule can be followed out in every case.

The construction of every piece of road is a problem in itself, and no definite rule, to be followed in all cases, can be laid down. It is only after thoroughly investigating the circumstances in each case, and every case that a final decision can properly be arrived at and the mode of procedure which seems most suitable for the place in question should then be followed out in each case. The nature of the soil upon which, and usually with

which the road is to be made, should be studied, the amount of water which will necessarily have to be taken care of, and the natural facilities for disposing of this water should also be considered. The amount and nature of the traffic which is likely to pass over the road is another question that should receive attention when planning the construction of any road.

No road may be said to be sufficiently well drained, even where surface drainage alone is all that may be deemed necessary, that has not a drain along each side of the travelled way. The practice in vogue in many municipalities in this Province of constructing a ditch along the road allowances and piling the material excavated therefrom in a more or less irregular pile anywhere from one to twenty feet from the side of this ditch, is not conducive to producing the best results. As stated above, the prevailing conditions must be considered in all cases. If the foundation over which the road is to pass, is composed of heavy retentive material, that is not liable to be eroded by the action of the water passing through the ditches, the edges of the road grade should be close to the inside edges of the ditches, leaving at the most only about three or four feet of berm between the ditches and the road grade. In fact, there is no apparent reason why the inside slopes of the ditches should not be continuous with the corresponding slopes of the grade, except it be in cases where the soil is light and free and where a large amount of water running through the ditches down a heavy decline would be liable to undermine and destroy the road by erosion.

Water should not be allowed to stand in ditches or accumulate to an excessive amount.

The water collected in road drains should be emptied into the natural runways as quickly as possible and not permitted to accumulate in these drains to an excessive amount. Every available watercourse should be utilized for this purpose so that the danger of damages by erosion and flooding may be lessened to the greatest extent.

It is very frequently found that these watercourses require to be brushed, deepened, straightened or otherwise improved for the

Natural water courses should be improved where necessary to facilitate the disposing of water.

whole or sometimes a portion of their length to the larger rivers, so as to enable them to properly and safely handle the flow of water—emptied into or otherwise collected by them. Money spent where necessary in improving these waterways is money well spent. It is almost impossible to have too many offtakes to relieve the water col-

lected in road ditches, because wherever there is water left lying along a road there is always sure to be a mud-hole develop in the surface of the road itself.

The scarcity of well defined waterways a great hindrance to the acquiring of good drainage.

It is the scarcity of these well defined waterways that makes road building in many parts of Manitoba so difficult and expensive. Districts, where their absence is noticeable, are usually characterized by the presence of large areas of low-lying lands which during wet seasons of the year are more or less inundated. The drainage of these lands, which is so essential to the construction of roads throughout it, is rendered more expensive by the necessity of having to carry the water so far through ditches to watercourses or creeks into which it can be safely emptied, necessitating in this way the construction of larger drains.

Drainage can be effected in some cases by following road allowances.

In some instances the drainage of these lands can be very well effected by draining along the road allowances until they are intersected by watercourses of adequate capacity to handle all the water. In such cases the material excavated from these drains can be made to form the bases of roads. But it is only natural to expect that this course cannot be followed out in all cases with equal success as the road allowances which follow along the surveyed lines of the sections were laid out regardless of the nature or topography of the country.

Conformity to general lie of the land absolutely necessary to secure good drainage.

Hence it becomes absolutely necessary in order to obtain good drainage, either for the reclamation of low lands, or carrying out the construction of well-built roads across them, to conform to the general lie of the land and to lay out drains or systems of drains accordingly. The decided aversion which many people have to the construction of drains or the improving of watercourses across their lands, when such a course seems to be the only feasible one to accomplish the desired results, is a great obstacle in the way of securing good drainage. The fact should be borne in mind that by following the natural flow of the water, in improving existing watercourses or in constructing new channels, the results will always be attended with better success, and less liability to damage by flooding or erosion. It is also very undesirable, in-

Regard for the safety of travel should be observed in road construction.

Future requirements should be considered when making extensive improvements.

The expectation that all leading roads can be and probably will be macadamized, gravelled or otherwise improved in the not too distant future should govern the present treatment given them everywhere. The labor and money expended upon them should be done in such a way that it will not only count towards the betterment of their present conditions, but also towards their ultimate improvement as hard roads. For this they will require attention (1) to their location, (2) to their drainage, (3) to their grading.

Location of roads should be permanently settled from the first if possible.

The location of the great majority of roads in this province is not a difficult task, as the fixed rule of following the surveyed lines of the sections is almost universally adhered to. The only deviation from this set rule is where the natural physical features of the district render such a course impracticable, as where large bodies of water or impassable sloughs intervene, or in constructing a road into or out of the deep valleys of the large rivers of the province. It is in instances such as last-mentioned that care should be exercised in settling upon the final location of a road, in order to see that the best possible site is obtained and the easiest gradients consistent with good location secured. It is poor business to keep on spending money on a road which will have to be abandoned eventually on account of excessive gradients or improper locations.

K.S. ?)
x { **Gradients on hills should be restricted to 4% or 5% and 7% should be the maximum permitted.**

An effort should be made to restrict the grade on a road to four (4) or five (5) per cent or a rise or fall of four or five feet vertically to every hundred feet horizontally. Seven (7) per cent should in any case be the maximum allowed in permanent road construction. Four (4) or five (5) per cent is about the maximum grade that a team of horses will trot up or down without considerable difficulty, and as the grade increases above this limit the load that a team can pull up it decreases very rapidly.

In laying out a road, the side ditches should be so spaced that sufficient room will be left between them for a grade wide enough to accommodate the present traffic, and as far as can be reasonably judged for a width sufficient to meet the require-

Road should be placed in centre of allowance set aside for that purpose.

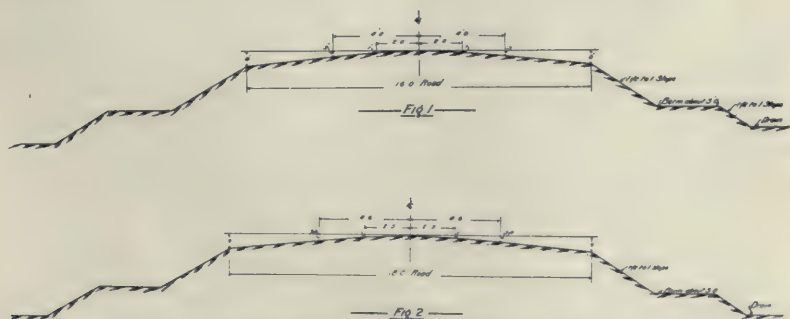
ments for future use. The travelled roadway should be situated in the centre of the road allowance unless there is some obstacle preventing this being reasonably done. The inside edges of the drains should be twenty-eight (28) feet apart where the height of the grade does not exceed about two and one half ($2\frac{1}{2}$) feet, as it seldom does, except it be on the approaches to the floor level of a bridge. It is much better in such cases to keep the drains well back from the toe of the slopes of the fill, so as not to weaken the foundation and also to avoid as much as possible any danger of undermining the fill by the action of water.

Travelled roadway should be from 16 ft. to 24ft. wide.

The travelled roadway should be made at least sixteen (16) feet wide on all highways and this should be increased to eighteen (18) feet on main trunk roads in the rural districts, increasing to twenty (20) feet nearing a town where traffic is always sure to be heavier, and they should attain a width of twenty-four (24) feet on approaching a city.

Slopes of earth grade should be $1\frac{1}{2}$ to 1 or 2 to 1 for light material.

The sides of an earth fill should slope towards the ditches at an inclination of at least one and one half ($1\frac{1}{2}$) feet horizontally to every one (1) foot vertically. This might well be flattened to two (2) feet horizontally to one (1) foot vertically if the material is inclined to be of a very light nature.



Figs. 1 and 2—Cross-sections of Earth Roads. Typical of Scraper and Elevating Grader Work.

Earth roads should be crowned sharply.

The earth road requires to be crowned considerably more than roads made with harder and more impervious material. The susceptibility of an earth surface to absorb water demands that precaution should be taken to facilitate the escape of any water that may fall upon it by allowing it to pass freely and quickly into the side drains, thus preventing to a large extent its damag-

One inch to the foot fall necessary for crown on earth road.

ing influences. A fall of one (1) inch to the foot at least should be given the surface from the centre of the road towards each side, and on steep hills this fall might be increased to an inch and one half ($1\frac{1}{2}$) to the foot, so as to prevent as far as possible the water from following the wheel tracks down the centre of the road instead of flowing into the side ditches and in that way probably cause considerable damage to the road.

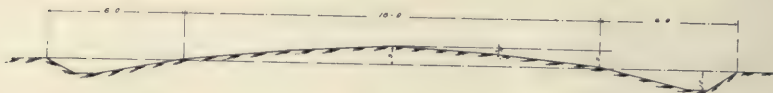


Fig. 3—Cross-section of Earth Road made with Push Grader.

CLEARING AND GRUBBING.

The right-of-way for a road should be cleared of all timber and brush for its entire width. If the trees are not cut down for a distance well back from the road, the soil will be kept moist for an undue length of time. This will have an injurious effect upon the road as the earth will be left in a condition more susceptible to rutting by the wheels and traffic upon it. The only exception to this will be where the natural formation is sand. The conservation of a certain amount of moisture in this material will assist it largely in holding up traffic, as it will enable it to present a more solid and compact surface.

All timber on the right-of-way, except that portion upon which the road is to be constructed, should be cut close to the ground, cut up in lengths and hauled away to be made use of, or if unfit for any purpose it should be burned.

The timber on the portion of right-of-way to be graded should be grubbed out by the roots except where there is to be an embankment of three (3) feet or over, when it might be close cut. In the matter of grubbing, it will be much easier and more economical to grub the roots out when felling the

tree rather than to cut down the body of the tree and then dig out the roots and stump. The main roots might first be cut and the tree used as a leverage when falling to help break off and tear out the roots. Very often blocks and tackle fastened to a convenient anchorage and up the body of the tree will assist greatly in moving a heavy tree with long tenacious roots.

The right-of-way might be cleared by contract at so much per acre. The following table showing acres per mile for different width of right-of-way will assist in estimating the cost of such work:

One Mile of Road

1	foot	wide contains		0.121	acres
10	feet	"		1.21	"
16½	"	"	(1 rod)	2.00	"
20	"	"		2.42	"
30	"	"		3.63	"
33	"	"	(2 rods)	4.00	"
40	"	"		4.84	"
49½	"	"	(3 rods)	6.00	"
50	"	"		6.06	"
60	"	"		7.26	"
66	"	"	(4 rods)	8.00	"
70	"	"		8.47	"
80	"	"		9.69	"
82½	"	"	(5 rods)	10.00	"
90	"	"		10.90	"
99	"	"	(6 rods)	12.00	"
100	"	"		12.12	"

HILL - SIDE ROADS.

Location of hill - side roads. Roads constructed on a hill side should receive careful consideration with regard to their location, because when once the location is decided upon and actual construction started, it is a very difficult matter to change without sacrificing a great deal of money and labor. If a portion of the road subsequently appears to be unsatisfactorily located, the altering of it will in a great many cases involve the changing of the whole or a very large part of the entire location, in order to make the altered portion fit in or correlate with the remaining portion. So it becomes very apparent that the question of location is one that should be dealt with thoroughly from the beginning.

**Roads partly
in cutting
and partly on
embankment.**

When the road lies along the side of a hill so that it is partly in cutting and partly on embankment, it is necessary to so place its centre line that these two parts of the cross-section may balance. On a side hill with a uniform slope the amount of cutting should be a little in excess of the amount of fill so that sufficient material will be secured to make up the embankment in a compact and solid mass to the required size. For a road sixteen (16) feet wide usually nine (9) feet in cutting and seven (7) feet on embankment will properly balance the cross-section, when the slope of the cutting is taken out to the same angle as the constructed slope of the embankment.

On a hillside it is often recommended that the surface of a road should consist of a single slope inward as shown in figure No. 4, instead of assuming a convex surface as on any ordinary



Fig. 4—Cross-section of Earth Road on Hillside.

road. The former method will have an advantage with regard to safety, especially on a narrow road when vehicles in passing might have to approach quite close to the edge of the road and again it would be well to keep the outside edge high on account of the settlement of the material at that point being greater from the additional height of the fill, and also on account of the natural tendency of the material—especially earth—in such position to slide off or break and the edge of the road become rounded to an undue extent.

Offtake drains. The drains or gutter along the road on the side of a hill should be connected very frequently with offtakes leading down the hill and away from the road. A large amount of water should not be permitted to accumulate in them, as the danger of washouts from a large flow would be almost certain on an earth side hill. The water should be intercepted by all natural courses crossing the road and carried through in culverts

Culverts should follow in line with the natural watercourses.

of adequate capacity. The culverts should be constructed following the line of the original watercourse across the road. No attempt should be made to divert these courses on the side of a hill for the sake of having it cross the road at

right angles that the length of the culvert might thereby be lessened. Such a proceeding would be attended with no small amount of danger from washouts, and any attempt in economis-
ing, which at first might appear warranted,
 very often proves to be the source of extra expenses for repairs and continual anxiety with regard to the safety of the road. //

Catch water drains.

The construction of catch water drains as shown in figure No. 4 may very often be done to good advantage, and may be the means of protecting the road to a large extent, especially where it is situated with an extensive sloping area above it. These drains need not be of very large dimensions. Being located on a hillside, sufficient fall for them can be easily obtained and their capacity raised to the requisite amount.

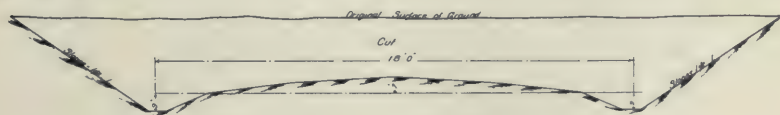


Fig. 5

Fig. 5—Cross-section of Earth Road in Cut.

Camber on surface in cuttings.

In cuttings the surface of the road should receive the same attention with regard to its camber as ordinary roads on embankments. Care should be taken to see that the fall from the centre of the road to the gutters on the sides exceeds the longitudinal fall, so that water will not follow along the wheel tracks, but find its way to the side ditches.

Slopes in cuttings.

The slopes of the cuttings should be taken out to an angle at which the material will stand, and in regard to this the nature of the material will have to be examined. The usual slope given to earth in cuttings is one and one half ($1\frac{1}{2}$) horizontally to one (1) vertically. The natural and strongest form of slopes for earth and the one which it will ultimately assume is in the form of a concave curve with the flattest portion at the bottom. This form is rarely given to slopes in constructing them; in fact, the reverse is very often the case, the slopes being made convex and left invitingly for slips to

occur with the least provocation. In cuttings exceeding ten (10) feet in depth, the forming of concave slopes will materially aid in preventing slips and in many cases they will reduce the amount of material which will eventually have to be removed when cleaning up. Straight or convex slopes in earth will continue to slip until the natural form is attained.

x { **Slope of hill should be furrowed to prevent embankment from slipping.**

The side of a hill upon which an embankment is to be placed should be stepped or furrowed as shown in figure No. 4, to prevent the material slipping down the hill. On hills with a moderate slope, furrows every (2) or three (3) feet taken out with a plough will generally suffice. But

where the hill is very steep revetment or retaining walls will have to be constructed to hold the embankment and save material in making it up. Where stones are abundant, a wall can be constructed with them for that purpose.

GRAVEL ROADS.

Gravel, which can be obtained in many parts of the province, though not as durable as stone, will prove very serviceable as a road covering. Moreover, it is a material that will form the base for the construction of a more durable type of road which may be required at a later date.

Earth surface should be properly drained and graded before gravel is placed upon it

Before putting gravel on the surface of roads, it is most essential that they should be properly drained, graded and straightened. The earth should be either consolidated with a roller, or allowed to become compacted and settled by traffic and the effect of time, before a coating of gravel is placed upon it. A good earth road is the fundamental requirement of every class of road.

Quality Gravel containing dirt, much clay, sand or earthy material should be avoided if possible. It usually packs readily, but in wet weather turns to mud quickly, ruts easily and soon wears out. The best gravel for road work is clean, free from an excess of sand or clay, and composed of stone varying in size up to one and one half inches ($1\frac{1}{2}$ ") in diameter, with enough fine stuff to fill up the voids and make a compact mass.

Large stones should be left in the pit and not hauled to road. Large stones should be raked off and not left on the surface of the road, and as much care as possible should be taken to have them picked out from the mass in the pit when loading wagons,

so as to avoid the trouble and expense of hauling them on the road where they are not required and are only a detriment and nuisance.

Hauling gravel The cost of gravelling a road depends largely on the cost of hauling the material from the pit. When teaming

A day's work should be fixed by a given amount of material delivered. it the size of the loads should be fixed and a definite number of loads of a given size constitute a day's work. One and one half ($1\frac{1}{2}$) cubic yards would be a fair average load for

a team. The ordinary wagon is 38" wide on the bolsters, and allowing three inches of this for the thickness of the side planks, the width of a gravel box would be thirty-five (35) inches. So in order to hold a yard and one half ($1\frac{1}{2}$) a wagon box would necessarily have to be ten (10) feet long and sixteen and three-quarters ($16\frac{3}{4}$) inches deep.

Laying the gravel. Gravel should be put down in layers, the first layer being about four (4) inches deep, and being a little deeper at the centre than at the edges. It should be carefully spread to a uniform width, varying according to the full width of the road, which of course depends on the amount of traffic thereon. The first layer should be well consolidated by the use of a roller before the next one is laid upon it. Usually a somewhat lighter coat will be sufficient for this second layer, which in turn should receive the same treatment as the first, and so on until the required depth is obtained. The quantity of gravel required depends to a large extent upon the nature of the soil over which the road is constructed, the consolidation of the sub-grade and the thoroughness of the drainage.  X

Amount of gravel required. On roads over a clay soil about one (1) foot of gravel carefully spread as above mentioned in layers should make a very serviceable road for country traffic. This amount when thoroughly compacted will give a thickness of between eight (8) and nine (9) inches. It is always well to have

A surplus of material should be placed conveniently for use in filling in depressions or ruts.

traffic is relied upon to do this.

Gravel hauled in winter is often done to advantage.

convenient piles of the gravel placed along the road, say about every five or six hundred feet, so that it will be in readiness for use to fill up depressions or ruts that may develop. This is especially necessary during the first stages of construction, and more so when the roller is not used to consolidate the gravel and when

It is very often convenient and sometimes can be worked to good advantage to have gravel hauled on to the roads in sleighs in winter, especially where the roads are situated a great distance from the pits. In such cases care should be exercised to have the road well drained and graded before freezing up. Any excess of snow lying on the roads should be shovelled off immediately preceding the gravelling so that it will not be kept from thawing for an undue length of time in the spring, by being covered with the gravel. The great advantage in having this work done in the winter is, the loads which can be hauled at that season are so much larger that the cost of hauling is reduced to about one-half the amount it would cost in summer, and again, teams and labor can usually be obtained more readily in the winter season than in the summer.

The gravel should be placed fairly on the centre of the road and spread in as straight a line as possible, which will make it a great deal more pleasing to the eye.

Width of gravelled portion. The gravelled portion of a road should be fourteen (14) feet at least in width in order to provide sufficient room for teams to pass with ordinary vehicles without having to turn off on to the earth sides.

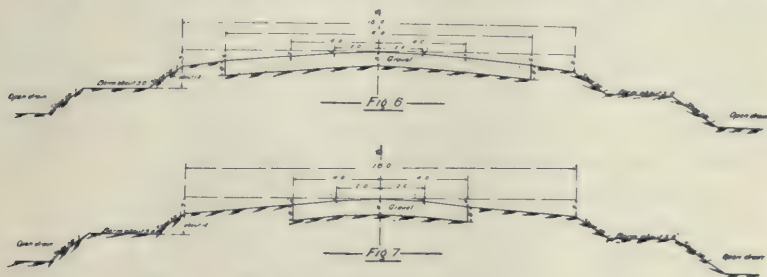
For rural roads this width might well be reduced to eight (8) feet. With the occasional passing of teams in the country, the inconvenience of having to turn off the edges of the gravel would not be so very great. Gravel will spread considerably of its own account through time where it is not shouldered up with earth to prevent it from doing so. When putting on the first coat in this way and depending on the traffic for its consolidation, if the gravel be spread about six (6) feet, it will probably be sufficient, as during the process of consolidation it is bound to spread some. In fact, it will require diligent attention for a time to keep it from spreading too much. The effect of wagon wheels passing over loose gravel, while it has a tendency to force the

Constant attention should be given to gravel road, especially in the initial stages of construction.

gravel down to a certain extent, has a greater tendency to push it out laterally, which, with the shifting action caused by the pounding of horses' feet, will scatter the material to an excessive degree if not attended to and continually kept in shape until it becomes well settled. Men should be constantly kept on the road until it attains this settled condition. They would be employed at raking any loose scattered gravel back into the wheel ruts, and keeping the road in shape generally. They could also draw upon the supply of surplus material which should be at hand in convenient piles as before mentioned, to repair any breaks which may develop in the road.

The construction of a gravel road, in a manner similar to the foregoing description, is a process which should lead to very fair results in districts where traffic is not excessive. If proper attention is given it, and light applications of gravel put on from time to time, it should develop into a substantial road. The one defect in a road of this kind is the lack of binding properties of the material. This is particularly noticeable in wet weather, when the wheels of vehicles becoming covered with sticky mud from travelling over intersecting earth roads pick up the particles of gravel, and also bring on to the surface of the gravel road an excessive amount of clay, which naturally falls from the wheels before going a great distance on the gravelled surface. This tends to unravel the surface and causes an excess of mud to become mixed in with the gravel. Objections of this nature must evidently be expected for a while, as it would be impossible to have all roads treated alike at once, but such conditions will rectify themselves to a large extent as more roads are gravelled, macadamized or otherwise provided with a hard surfacing material.

Fig. Nos. 6 and 7 are typical cross-sections of a gravel road.



Figs. 6 and 7—Cross-section of Gravel Road.
Gravel 14" 0' in width
Gravel 8" 0' in width

Gravel should be shouldered up with earth in order to form the best gravel road.

A gravel road can be much improved both in appearance and serviceableness, and also with a certain degree of economy, especially in districts where gravel has to be hauled a long distance to the road, and where any saving in the amount of material used would affect the cost materially, if shoulders of earth were built up against the gravel to retain it in position. This would make it more convenient for vehicles passing, as the shoulders would keep them in a more upright position when turning out to the sides. It would prevent the gravel from being scattered and to a large extent wasted by being pushed off the sides of the road.

Earth might be placed before or after the laying of gravel.

The earth for the shoulders might be placed along the sides of the road in the proper position and to the height which it is proposed to lay out the gravel, making a channed in which this material might afterwards be put down, or the gravel might first be laid to the required depth and the earth then placed against it. In this latter method great care should be taken so as not to have an excess of the earth scraped on to the gravel and mixed with it to the injury of road. This would be liable to occur if horses and scrapers were used for carrying up the earth from the side ditches after the gravel had been laid on the road.

After the gravel has been put down it should be properly spread and the earth shoulders neatly trimmed. The whole road should then be rolled until a solid, even surface was formed.

Main road should be gravelled where this material can be obtained at a reasonable cost.

Where gravel can be obtained at a reasonable cost municipalities should undertake to build up their main roads with it as a decided improvement is possible with an outlay that should not be considered prohibitive. There is no doubt that this material will make a satisfactory road, and for a number of years yet it will be quite suitable on the main highways in the rural districts of this province.

The following table shows the number of cubic yards per mile for widths ranging from six (6) feet to fourteen (14) feet, with depths from four (4) inches to twelve (12) inches:

**Table Showing Number of Cubic Yards of Gravel Required in
the Construction of One Mile of Gravel Road of
Widths Varying From 6 to 14 ft.**

Length in miles	No. of feet in width	Number of cubic yards in road					
		6 inches deep		8 inches deep		10 inches deep	
		Com- pacted	Loose	Com- pacted	Loose	Com- pacted	Loose
One mile	6ft. wide	587	880	783	1175	978	1467
"	8ft. wide	783	1175	1042	1563	1304	1958
"	10ft. wide	978	1467	1304	1956	1630	2445
"	12ft. wide	1174	1761	1565	2348	1956	2934
"	14ft. wide	1369	2055	1825	2738	2282	3425

CULVERTS.

Proper culverts for carrying the water from one side of the road to the other should be constructed in the road wherever they are required. In most cases it will be only necessary to have one of the side ditches along a road made continuous to the outlets, constructing the other with its base inclining to the lowest depression along its course, where it should be connected with the main ditch by a culvert of adequate capacity to carry away all the water that may be collected in it. In this way the deeper cuttings rendered necessary for the proper drainage of the road will be confined to one ditch only and a great saving made in the cost of the work, as the other ditch need not be so deep or large, more especially so as it approaches the higher ground on each side of the depression.

Care should be taken in constructing these culverts so that they may have sufficient fall across the road to clear themselves, and they should also be placed sufficiently deep to permit all the water to escape from the higher ditch. The invert or bottom of the culvert should be as nearly as possible in a line with the bottom of the ditches. If the water has a decided drop from the end of the culvert into the ditch a heavy flow is liable to scour and undermine the end of the culvert.

All culverts should be made of sufficient length. A great mistake is oftentimes made in having them too short, and a culvert in this position is a menace to the safety of travelling. It is much better to have them extend from ditch to ditch. The slight difference in the length will not cost a great deal more and is well worth any additional expense.

The ends of culverts should be protected by head walls of concrete, masonry or stone to prevent erosion and undermining. The surface of the ground upon which the culvert is placed should be solid and so shaped that the culvert will have an even solid bearing, so as to enable it to withstand the weight imposed upon it. If circular pipes are used a concave bed should be excavated so as to fit the shape of the pipe; and if the foundation is soft and springy, this material should be dug out and the space filled with gravel or other hard durable material.

The joints of all culvert pipes should be made tight with cement mortar. If water is permitted to escape, a considerable channel is liable to be worn through the earth along the outside of the culvert. It will also be advisable, especially on pipes with a large diameter, to fill in between the sides of the trench and the joints of the pipe with concrete, extending about half way up the pipe. This will assist greatly to hold the pipe in a straight line and obviate any danger of the joints separating when the trench is being filled in.

The material should be carefully tamped around the pipes, precaution being taken to have the filling go well under them, so as to aid the pipes in withstanding the weight of traffic over them.

At least eighteen (18) inches, and preferably two (2) feet, of material should be placed over culverts to protect them from crushing. But under no circumstance should the material be heaped up and left projecting above the surrounding road surface; nor should there be a depression left in the surface over the culvert. The material for filling should be brought up flush with the surface of the road, leaving neither knoll or hollow for vehicles to go bumping against or into, to the injury of the road and vehicles and to the discomfort of everyone using the road.

At all road intersections the grades should be widened so as to provide a suitable turnoff for traffic desiring to take the turn, and at these points culverts should be of sufficient length to allow this to be done. If the grades are left narrow at these points, it is very difficult for a traction engine hauling a separator and tank to make the turn, and is also very dangerous for ordinary traffic, as vehicles are liable to be upset by running off the edge of the road grade. ✓

If culverts are required (as is generally the case) through the roads at these junctions, they should be as nearly as possible

in a line with the ditch, the water from which they will have to carry, and as mentioned before they will have to be made sufficiently long to allow for a proper turn at the crossing. Very often culverts so situated are too short, making it impossible to build a crossing with sufficient room for traffic to turn with ease and safety, and sometimes the ends of culverts in this position have become blocked with earth or other material by being pushed over the edges of the road by traffic which is compelled to turn on a narrow crossing. Again, there is the danger of the ends of the culverts being smashed by vehicles striking them when they are forced so close to the edges of the road.

If there is only a very small amount of water to be handled by culverts at road crossings, and the fall of the ditches is not so great as to cause a wash by striking against the intersecting grade, the culverts might be placed back from the crossing at points where the road resumes its normal widths. A saving can thus be made in the length of culverts required. This should only be resorted to, however, when the amount of water to be

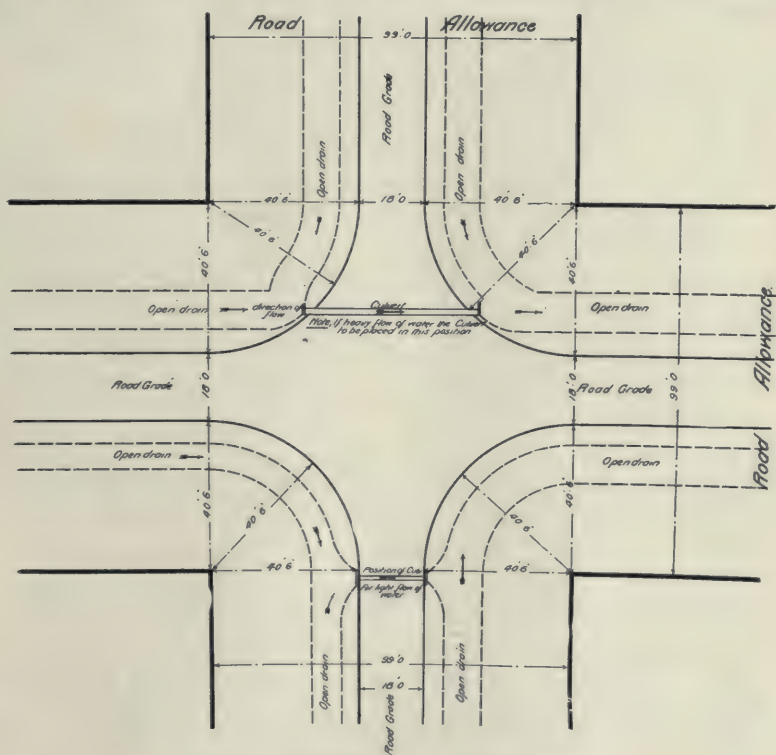


Fig. 8—Intersection of Rural Roads.

controlled is very small and can be safely turned from its course for a short distance. Figure 8 shows a general lay-out at the intersections of rural roads.

Apart from the small structures built through a road grade, or in an open drain at a road crossing, or at a farm entrance, which are known by the name "Culvert," there are others that receive this appellation. In fact, any structure that is built for the purpose of carrying a stream of water through an embankment or road may be known by that name, and in that way distinguished from a bridge which is a structure built over any body of water, valley, depression or the like for the convenient carrying of traffic.

Culverts should be of a permanent character.

The construction of culverts of all kinds is a very important factor in the building of roads. Their position in the road is invariably at the lowest points along its course and therefore the wettest, and as a rule the most difficult to maintain. The absence of a good and sufficient culvert at a point where such a structure is essential renders even an otherwise first class road of little value for traffic at critical seasons, and at all times diminishes the importance and value of the road to the community concerned.

It is not the traffic in most instances that destroys these structures, but the elements, so that a good permanent culvert is as much in place in an earth road on any side line as it is in the most heavily travelled highway. The best class of road material will require renewals and repair, but it is possible to build the small structures so as to eliminate maintenance and make them practically everlasting. It is therefore a short-sighted policy to use any other material than that recognized as the most permanent.

Wooden Culverts should be avoided.

Wood as a material for culverts should be avoided as much as possible. Being subject to the continuous action of water and the elements it soon rots, and falls to pieces.

Concrete as a material is adaptable to the construction of culverts.

Concrete, either plain or reinforced, is peculiarly adaptable for the construction of culverts. It has become to be extensively used as a substitute for stone or brick in the building of culverts, bridges and retaining walls. It requires no repairs when once properly laid in place, and many examples

are to be seen where it has stood for fifty (50) years without signs of deterioration whatever.

Some reasons for failures in concrete. Failures in concrete work are largely due to unexperienced supervision and the lack of proper inspection of the proportioning and mixing of the materials; the placing of the concrete and caring for it until it has sufficiently hardened. In order to ensure first-class work it is most necessary to use good material and to have a thoroughly competent man in charge.

Culverts should be of ample dimensions to carry the water imposed upon them.

In putting in a culvert with a view to permanency, it is of the utmost importance to consider the amount of water that has to be carried through it, and its capacity should be determined and made adequate for not only the existing flow, but for any additional flow that may have to be cared for from future drainage arrangements. The estimating of the amount of water to be discharged through a culvert is often a difficult one. While it is certainly much better to be on the safe side and have a little more area than is absolutely required, yet it is well to keep within reasonable bounds and not to be too liberal in this regard. It must be admitted, however, that more mistakes have been made by constructing culverts too small and thus retarding the flow of water in its natural course than by giving them an excessive water area.

Estimating size of culverts. In many cases the necessary size of a culvert can be approximately obtained, firstly by careful observation of the existing openings on the same stream; secondly, by measuring, preferably at high water, a cross-section of the stream at some narrow place; and thirdly, the height as indicated by drift and evidence of the inhabitants of the neighborhood. Several other considerations have to be taken into account, such as the condition of the soil, the inclination, alignment, and character of the bed of the stream, the form of the mouth and the inclination of the bed of the culvert. The discharging capacity can be greatly increased by increasing the inclination of the bed of the culvert, providing the course below its outlet will allow the water to flow away freely after having passed through it.

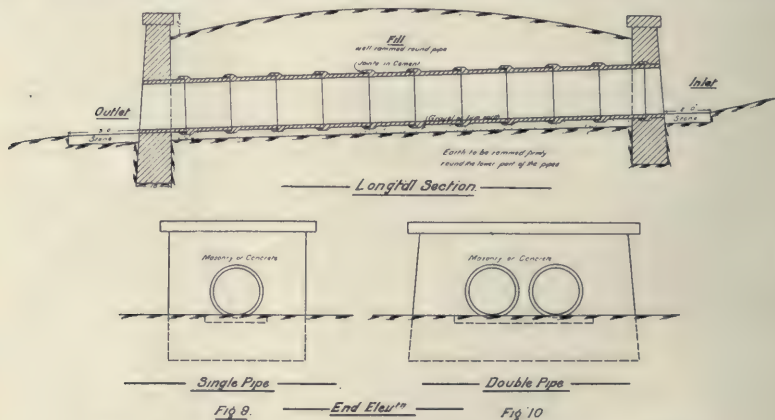
Culverts should be built in line with course of stream.

Culverts should be placed as nearly as possible in a line with the stream. Very often serious mistakes are made in constructing

the culvert at right angles to the direction of the road in order to have a few feet in its length. In this case the water has to be turned before entering the intake of the culvert, which has a tendency to cause washouts and undermining, and often serious injury to the structure. The cost of thoroughly protecting the ends of culverts and the road grade when the channel is diverted so as to cross the road at right angles, is very frequently more than the extra length of culvert required to cross the road at an acute angle, and is seldom as secure from injury as when the natural run of the water is followed.

Concrete or vitrified earthenware pipes suitable for flow of water.

For small streams and a limited amount of water, pipes either of concrete or vitrified earthenware, varying in sizes from twelve (12) inches to twenty-four (24) inches, will serve excellently. They are easily laid, and if properly bedded with earth well tamped about them are very permanent. This upper surface should be at least eighteen (18) inches below the road surface and their ends should be protected by head walls, which also has the effect of retaining the fill over the culvert and preventing the earth from being washed into the ends of



Figs. 9 and 10—Plan of Pipe Culvert and Head Walls.

the pipe. Figure 9 is a view of a single line of concrete pipes with head walls of boulder stone, masonry or concrete. Figure 10 represents a double line of a similar construction.

Danger of pipes from bursting by frost if not properly drained.

The freezing of water in the pipes, particularly if more than half full, is liable to burst them, consequently the pipes should have a sufficient fall to drain themselves, and the outlet should be in such shape that the water discharged through

them will get away quickly from the culvert and not be permitted to lie in it. If the pipes are properly drained there is no danger from frost. The mouth of a pipe should never be allowed to become submerged.

Jointing. In many cases, perhaps in most, when laying pipes for road culverts the prevailing custom in this province is to leave the joints uncaulked. This should not be so, as there is a liability of the water being forced out at the joints and washing away the soil from around the pipes. Even if the danger is not very imminent, the joints of the larger pipes at least should be caulked with hydraulic cement mortar made of neat cement. A little of this should be mixed at one time as it is required, and pushed well into the flange of the pipe with a trowel. Care should be taken to clean away any of the mortar from the inside of the pipe that may have been forced through the joint. This precaution against injury from a leakage of water through the joints is commendable, since the cost is very small compared with the insurance against damage secured thereby.

Shape of culvert should suit the character of the stream.

Where the height of the fill from the bottom of the bed of the stream to the level of the road grade is limited, and where a large area is required for the passage of the water it will be much better to adopt a form of culvert with a cross-section low and broad rather than to raise the grade of a road over a high culvert. Thus the full area and capacity of a culvert with low walls and a broad base can be utilized without it being necessary for the water to rise to an unnecessary or dangerous height, which is an advantage in handling the water in many of the streams in this province.

Box culverts. A very common type of culvert and one which is simple in its construction is the box shaped culvert. It can be made from concrete, and from the fact that it is monolithic its efficiency and strength is somewhat superior to the jointed pipe culvert. The barrel or box may be constructed to any rectangular shape which will suit the cross-section of the stream. They can be designed to resist the weight from any depth of embankment, which may be necessary to place over them so as to bring the surface of the road up to a proper elevation. The use of steel reinforcement in conjunction with hydraulic cement concrete will very often be more economical, if properly designed, than plain concrete, as the amount of concrete then used may be considerably reduced. For spans over ten (10) feet,

and providing the height does not exceed four (4) feet, it will generally be found advisable to construct a partition wall running the full length of the barrel, in order to support the roof of the culvert in the centre of the span, and thereby reduce the thickness of the material in the roof. In this way the culvert will take the form of a double box.

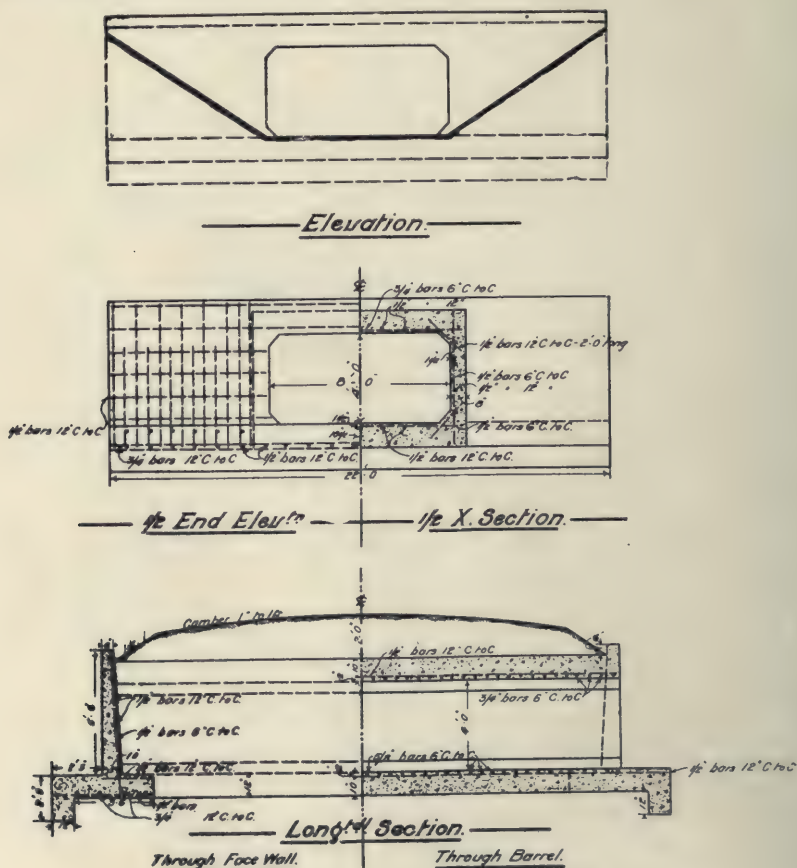


Fig. 11—Reinforced Concrete Culvert, 8ft. span.

Wing or head walls. Whatever shape of box is used it will be necessary to construct head walls, in order to retain the earth filling around and over the culvert, and also to protect the ends from being undermined by the flow of the water. These wings should be constructed simultaneously with the balance of the culvert, so that the whole will be a continuous monolithic structure. They may be constructed at any angle to the barrel of the culvert and in that shape which will best suit the loca-

tion. A head wall, constructed at right angles to the barrel of the culvert and continued the proper distance along the face of the embankment, is a very common form of construction, and is shown in Figure 11.

Figure 12 shows wing walls constructed at an angle of 30° to the barrel of the culvert. This style is a little more difficult to construct, but often meets the exigencies of the situation more satisfactorily.

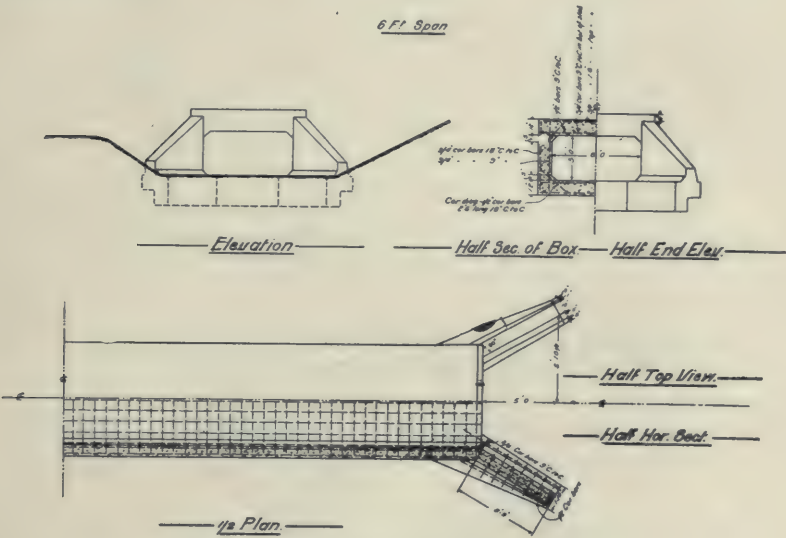


Fig. 12—Reinforced Concrete Culvert.

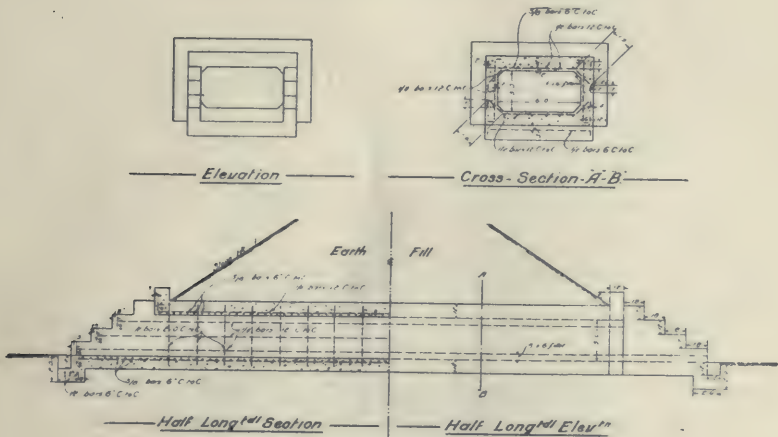


Fig. 13—Reinforced Concrete Culvert, 6ft. span.

The construction shown in Figure 13 is suitable for culverts where there is a very moderate flow of water, and where the current at the entrance of the culvert will be slow. It is simple in its construction, the wings being merely projections of the side walls of the culvert, extending a sufficient distance to retain the slope of the earth embankment. They should be sloped or stepped at an angle to correspond with the angle of repose of the earth in the embankment. The bottom or invert of the culvert should be continued out in a line with the ends of the wings with a baffle wall or apron along the outside edge, extending downward at least one (1) foot as a further protection from scouring at the ends of the culvert. The details of this wall are shown in figures 11, 12 and 13.

BRIDGES.

Substantial bridges are necessary. The construction of substantial bridges on the public highways is an urgent necessity to ensure the safety of all who use them. They must be strong enough to sustain all the traffic which may come upon them. Traction engines with their trailing loads of separator and tanks subject the highway bridges of the rural districts of this province to the greatest strains put upon them, and the tendency of late years has been to increase the weight of these engines; to what extent their size and weight will continue to develop it is difficult to foretell, but provisions should be made to meet these conditions as well as possible in designing structures for future use.

The designing of a bridge is exclusively the work of an engineer. The designing of all important bridges and the preparing of the necessary specifications should be placed in the hands of a reliable and qualified engineer. They are matters in which is involved not only the expenditure of large sums of money, but the safety also of the travelling public is dependent upon the successful working out of their many details.

Length of spans. A most important matter to consider in the design of a bridge is the length of span or spans to adopt to suit the location. Sufficient waterway should be provided for. It would be much better to have an excess of area for this purpose rather than a deficiency. It is the extreme floods that occur once in a period of years that should be provided for, and if this is neglected and the waterway is restricted to accom-

moderate the ordinary maximum flow only, serious washouts which may result in the total destruction of the bridge may follow.

Height of bridges above water line. All permanent bridges should be constructed at an elevation well above all levels reached by flood waters. In a district, which is timbered along the banks of the streams or rivers, drift wood is liable to be washed from the shores and carried down stream by the current. More especially is this true when the rivers are running full. Bridges located on such a stream should be well above the reach of any stick of timber which might be floated down against it, because the lodging of one stick against a bridge is liable to cause a jam of such proportions that would endanger the whole structure. The lowest point of the superstructure should be at the very least three (3) feet above the highest level that water may ever be expected to attain.

Timber bridges. While timber as a material for bridge construction is quickly passing out of use, there are certain sections of the country in which suitable material of this nature is procurable, and with which bridges may be erected with a certain degree of satisfaction and economy, especially on sites where pile structures will meet the requirements. In large and important structures, however, the saving in the initial cost of timber bridges is soon lost in the repairs and renewals of the same.

Pile bridges. The most common type of timber bridges is the "pile" bridge. They are suitable for structures across ravines, depressions or streams, which are free from the flow of drift wood, ice or other floating material that is liable to jam against the piles and cause serious damage thereby to the whole bridge. Care should be taken to see that piles are well driven and nothing but the soundest and best timber is used for this purpose.

The following specifications for pile bridges should be strictly adhered to when erecting this type of bridge, and should become part and parcel of a contractor's agreement with the municipality when the work is being carried on by contract.

SPECIFICATIONS FOR PILE BRIDGES.

Piles. All piles to be of good, sound, live Tamarac of the number and length shown on drawings, straight, straight-grained and not less than 13 inches at butt, or 9 inches at point and with bark removed. They must be close trimmed and properly pointed, and must be driven in position as shown on plan, pro-

perly spaced at ground and under caps. The piles are to be driven with a hammer weighing not less than 1600 lbs. for at least 10 ft. into the ground, and until the pile does not sink more than 2 inches with a 20 ft. drop of hammer. The driver leads to be wide enough apart to take the piles without being scored. Piles must be ringed. Split or otherwise damaged piles must be replaced at contractor's cost. In sawing off the piles, straight edges must be used attached to each side of bent at the proper height, upon which the saw will rest, so that the tops of piles will be perfectly level, and afford a true and even bearing for the caps. All work in connection with the pile driving must be done under the supervision of a competent Inspector, to be appointed by the municipality.

Timber. All timber must be of Douglas Fir, Red Pine or Tamarac, B.C. Bull Pine will not be accepted. It must be perfectly sound, of good quality, free from loose or black knots, shakes or waness, and truly sawn to the full sizes required.

Iron. All iron work to be of the best quality, of sizes and designs shown. All screw bolts to have 2 cast iron washers proportionate to the diameter of bolts. Nuts are to be tightly screwed up when in position. Holes for drift bolts to be bored $1\frac{1}{16}$ in. less than diameter of the bolts.

General. The drawings are made to scale, but in all cases where measurements are given they must govern, and the contractor must carefully examine and strictly adhere to the plan. The whole work must be carried out and completed in a thoroughly workmanlike manner by competent carpenters, in accordance with the drawings and this specification, and to the entire satisfaction of the Engineer appointed to inspect the same. The contractor must remove from under and around the bridge, and carefully burn, all chips, bark and rubbish. The decision of the Engineer on any matter relating to the quality of the material or the construction of the bridge shall be final. No claim for extras will be allowed, except on written authority of said Engineer, which must be obtained before any such extra work is undertaken.

Length of span between pile bents. It is the usual practice in erecting pile bridges to place the bents of piles—four (4) piles generally constituting a bent—with a clear span of fourteen (14) feet. By increasing the dimensions of the stringers the length of the span can be safely increased up to twenty-

eight (28) feet, in order to meet the requirements and exigencies of any particular location.

The following table gives the number and dimensions of stringers for eighteen (18) and sixteen (16) feet roadways for clear spans ranging between twelve (12) and twenty-eight (28) feet, to carry safely the weight imposed upon them by an 18 tons traction engine and its trailers:

Table Showing Dimensions of Stringers For Spans Varying From Twelve (12) to Eighteen (18) Feet.

9 stringers for 18' 0" roadway	
8 stringers for 16' 0" roadway	
Clear span in feet	Size of stringers.
12' 0"	4" x 12" — 14' 0" long
14' 0"	5" x 14" — 16' 0" "
16' 0"	6" x 14" — 18' 0" "
18' 0"	6" x 14" — 20' 0" "
20' 0"	5" x 16" — 22' 0" "
22' 0"	6" x 16" — 24' 0" "
24' 0"	7" x 16" — 26' 0" "
26' 0"	7" x 16" — 28' 0" "
28' 0"	8" x 16" — 30' 0" "

Earth fill against end bents should be limited to six feet in height.

When it becomes necessary to retain the earth fill with the end bents of a pile bridge, the outside surface of the piles may be planked with three (3) inch boards nailed to the piles and against which the earth may be placed. The depth of earth fill placed in this way against an ordinary bent of four (4) piles should not exceed six (6) feet; any additional depth will produce a greater strain than the piles can withstand with safety, with the consequence that the piles will be broken or bent out of a perpendicular position and rendered incapable of carrying the end of the floor system. No dependence should be placed on the stringers of a pile bridge to resist any strain from the weight of the embankment against the end bents. These bents should be designed as independent sections, as the connections to the piles of the timber caps which support the stringers being only $\frac{3}{4}$ " drift bolts are not designed to counteract a thrust from that direction. Where an excessive load has been placed against the end of a single bent of piles it has generally been found that these drift bolts have been bent and

When it is necessary to place a higher fill against these structures (and it has been found advisable to do so rather than put in extra bents of piles and extend the length of the bridge to meet the rising ground) special abutments should be designed to resist the increased pressure therefrom.



Large and permanent bridges. All large and important bridges should be constructed of steel on concrete or masonry piers and abutments, or of concrete construction throughout. It is common practice now to construct re-inforced concrete bridges with spans up to fifty (50) feet, and there have been many built with much longer spans. The usual form of construction for this class of bridge is an arch. It is satisfactory to know that bridges built of re-inforced concrete are secure, and while their initial cost may be slightly greater than wood or steel, yet when once properly erected, expenditures for costly renewals and repairs cease.

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the superstructure. Masonry and concrete are the two materials best adapted for the construction of piers and abutments. Timber should never be used for this purpose when the structure is being erected with a view to permanency, except it be to render more secure and stable the natural foundation upon which the masonry or concrete piers are built, and in this position it should be well protected from the destroying actions of the elements.

Good foundations are the first requirements of a permanent bridge It is a well known fact that timber will last for many years, if not for all time, where it is not subjected to the actions of the elements, while its usefulness will last for only six (6) or seven (7) years at the most when it is exposed. It is very poor economy indeed to use this material for foundations to carry a superstructure made from more durable material. Good foundations are the first requirements for a good substantial bridge, for without them the very best superstructure will be of very little use. A municipality in undertaking the erection of large and important bridges, should start at the bottom by building substantial sub-structures. If the funds are limited and the means at hand for constructing a permanent structure throughout are inadequate or the question deemed inopportune or inadvisable at the time, it would be better to erect a wooden span on good permanent piers and abutments than to erect a steel span on a foundation of timber. It is easier by far to put a new superstructure on an old foundation, than to build up a new foundation under an old superstructure. A mistake that many councils make in this province and for which there is very little excuse, is the placing of steel bridges on timber piers and abutments.

Engineering advice. Municipal authorities, when considering the erection of important bridges, should not hesitate to secure the advice and assistance of a competent engineer. It is not possible to fix on a standard plan; every bridge possesses more or less individuality, according to the site and location. The placing of wing walls, the amount of waterway to be provided for, the fixing of the height of the bridge, the style of superstructure adaptable to the location, the requirement of the foundation and many other details have to be considered.

Necessary preliminaries before asking for tenders. Before asking for bids for the construction of a steel bridge, a municipal council should first have prepared a plan showing the cross-section of the stream, the ordinary and high water levels at this

point, the relative positions and form of construction of the abutments and piers, the proposed elevation of the floor of bridge, the width of roadway, and should also state the type of bridge required, the kind of floor system — whether steel or wooden stringers with wood floor are to be used, or whether the floor shall be concrete. They should specify the live loading the bridge has to be designed to carry, the width of roadway, and furnish all the information of a necessary character to give a true idea of the plans and situation pertaining thereto.

Plans of super-structure generally submitted by "bridge companies."

Steel bridge companies much prefer confining their efforts to the construction and erection of the superstructures only, leaving the matter of substructure work to others, except where there is a large amount of steel used in the latter. It is their general practice to submit with their tenders plans for steel spans of their own particular designing. While the designs of the different companies differ but very slightly for the same specifications for loading, yet a thorough scrutiny of each plan should be made so as to be assured that all members are properly proportioned and designed, and to ascertain the most acceptable one from points of view of merit and cost.

Defects sometimes

noticed in a steel bridge.

The following are some of the defects which sometimes appear in a steel bridge:

1. Weak joints and connections.
2. Insufficient, small or badly formed rivets. (Shop rivets are usually satisfactory, but field rivets are frequently loose, badly formed, burned and bent.)
3. An inferior form of truss. (The amount and weight of steel in a truss is of very little account if the design is defective and weak.)
4. The use of inferior metal. (When steel is assembled and painted, it is a difficult matter to detect metal which is too hard, which has been rolled when cold or has other defects. Inspection for very large and important works often commence at the rolling mills or bridge works.)
5. The entire bridge or an occasional member may be too light. (This can only be overcome by a careful scrutiny of the plans by an Engineer who can determine the necessary size and shape of each piece of steel in the bridge for a fixed load.)

6. Defective field construction. (Field work must be examined to see that members are properly assembled and not injured. Under a careless foreman certain members may be bent and twisted.)
7. Insufficient attention paid to painting. (Inferior paint carelessly applied to rusted steel is a serious defect.)
8. Necessary bracing or members omitted.
9. End bearings do not always rest squarely and uniformly on the abutments, parts are not brought squarely together, spaces are left where water can lodge and cause rusting.

Selecting of site. The question of choosing the site of a bridge is an important one. If the selection is not restricted to a particular point, the river should be examined for a considerable distance above and below what would be the most convenient point for crossing, and if a better site is found the line of road should be made subordinate to it. The following are a few of the controlling conditions that should be observed in selecting a site:

1. Good character of the river bed, affording a firm foundation.
2. Stability of the river banks, thus securing a permanent concentration of the water in the same bed. (Cut banks are indications of erosion and instability of the material in the banks and should be avoided as much as possible.)
3. The longitudinal centre line of the bridge should be at right angles to the direction of the stream.
4. A straight reach above the bridge should be secured if possible. (Bends in the river are not desirable localities and should be avoided.)
5. Sharp curves on the approaches are undesirable. (The road leading on to a bridge should be as near as possible to a straight line for some distance from the ends of a bridge.)

Painting steel bridges. The life of a steel bridge depends to a great extent, not only upon the manner in which it has been first painted, but afterwards kept painted. Rust is the chief destructive agency to steel bridges. They should be painted at least once in four years.

The surface of the steel should be free from rust, scale, moisture or grease. This is removed by scraping with a steel scraper, and brushing with a stiff wire brush. If rust is left on under the paint it soon spreads, the paint will flake off and the material be exposed to the destroying action of the air and moisture. As some portions of the metal of a bridge are only five-sixteenths of an inch in thickness, it is evident that rust acting on both sides of such a member will soon weaken the structure.

A useful paint consists of red lead and lampblack mixed with pure raw linseed oil. The red lead and lampblack should be mixed first, in the proportion of about ten (10) pounds of red lead to one (1) pound of lamp black, and the linseed oil then added. It should be thoroughly stirred and mixed to a uniform consistency. The mixture should not be made too thin. About one gallon of the oil should be sufficient for eleven (11) pounds of the mixture of the other two ingredients.

The paint should not be applied to the metal in cold or damp weather, nor should drying ingredients be used.

MAINTENANCE.

Maintenance—so far as it applies to roads—is the work of keeping them as near as possible in their original shape and condition after construction, while repairs is the work of bringing them up to their original condition, rendered necessary by neglect to maintain them.

The maintenance of public highways is just as important as their construction. It is very little use to construct a road and then permit it to go to wreck and ruin for want of care and attention. No matter how well they be first constructed, they will deteriorate if not properly maintained.

Maintenance of the earth road. Drains and culverts should be kept open.

When once the drainage of an earth road is effected by the construction of the necessary side drains, culverts, bridges and outlets, it must not be presumed that they will always continue to perform their functions efficiently without being looked after. The bottom of drains very often become silted by loose material being washed by floods from their sides or from the road surface. This material will invariably lodge in the bottom of the drain where the fall along its course is light,—as it is impossible in all cases to obtain sufficient fall for a drain to make it self-cleansing. Culverts get choked up and prevent the passage of water. Outlet drains are

subject to the same conditions as side ditches. Therefore it is essential to keep a vigilant watch over these drains and culverts if they are to be expected to do their work of keeping the road free from the injurious action of water.

Waggon tracks should be filled and road surface kept smooth.

Again the surface of an earth road will become rutted by the heavy wheels of traffic passing over it; especially after a rain storm. If these ruts are not kept filled and the entire surface kept in a smooth rounded shape, the water which falls upon it cannot escape to the side ditch, but must lie upon the surface of the road until it is absorbed by the earth.

The split-log-drag. The split-log-drag is the most economical and efficient implement devised for keeping the surface of an earth road in proper shape. (See Fig. 14 and 15.) No muni-

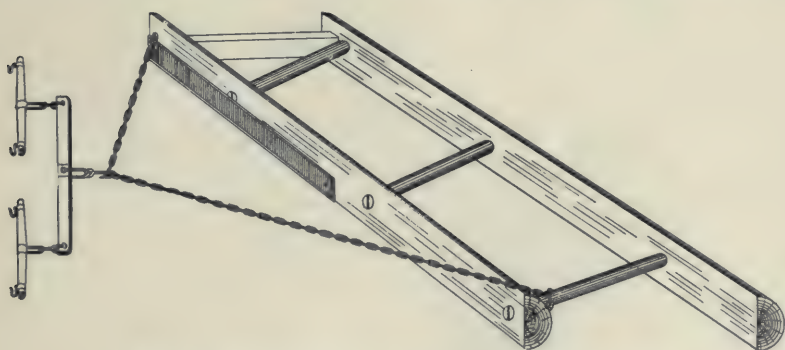


Fig. 14A—Perspective View of Split-Log Drag.

cipality should be without a number of them, so that they may be applied to their work on the roads whenever they are needed. It requires a little study of the nature of the ground and a little experience to determine the best time to use the drag after a rainstorm. The ground should not be permitted to become too dry or the drag will cause the rough edges of the surface to be formed into dust that will not again consolidate properly, or it will require too much weight upon it and hence too much horse power to manipulate it, in order to cut sufficiently deep into the surface to even up the hollows and ridges. Nor should the ground be too wet when the drag is applied, for if so, too much material is liable to be shifted and the surface disturbed for an excessive depth. The only case where it might be advisable to apply the drag to a slushy surface is when the ruts are deep and the road is in a very rough state. A trip up and down

with the drag might then be of some assistance in putting the road in such a condition that the proper appliance of the drag later, when the soil was in a more workable state, would be facilitated.

Generally, the ground should be moist, but not sticky. It should be in such a state that the edges of the drag will make a clean cut, and the earth which is loosened slip smoothly along the blade of the drag until it is dropped into a depression, where it is puddled into place by the drag passing over it. This cutting and puddling has a beneficial effect upon the earth, as it is well known that this material will become more impervious when puddled into place and permitted to dry in that state.

Shoulders along side of road should be kept trimmed.

The shoulders along the sides of the road should not be allowed to project above the general surface of the road. In this position they will prevent the escape of the water to the side drains. When once they become high, they should be cut down and made to conform with the surface of the road. The berms, if any, between the grade and side ditches should be kept smooth and free from weeds, etc. In fact, there should be nothing to interrupt the flow of water to these side ditches.

Culverts should be cleared regularly to prevent choking.

Culverts should be inspected regularly to see that they do not become choked up with sticks, weeds or earth that may be carried into them. The choking up of a culvert and prevention of the water passing through it may often cause serious wash-outs on a road that will cost money—and sometimes a considerable amount of it—to repair. In the spring of the year the ends of culverts should be cleared of snow or ice that may have gathered during the winter season. This attention will cause a flow through the culvert much sooner and often prevent the water from being dammed up against the side of the road.

Maintaining gravel roads.

The same attention should be given to the drains, etc. along a gravelled road as to those along an earth road. Good drainage is just as essential to one as to the other.

The drag may be used to good advantage in filling in the wheel tracks on a gravel road. Traffic has a great tendency on all roads to follow in much the same track—this is indeed difficult to prevent—consequently the two portions of the roads over which the wheels pass is subjected to much more wear and tear than the balance of the road. Therefore it is necessary

to see that these portions of the road are strengthened from time to time to prevent the gravel surface from being broken through. An endeavor should be made to keep a uniformly shaped surface free from depressions and ruts.

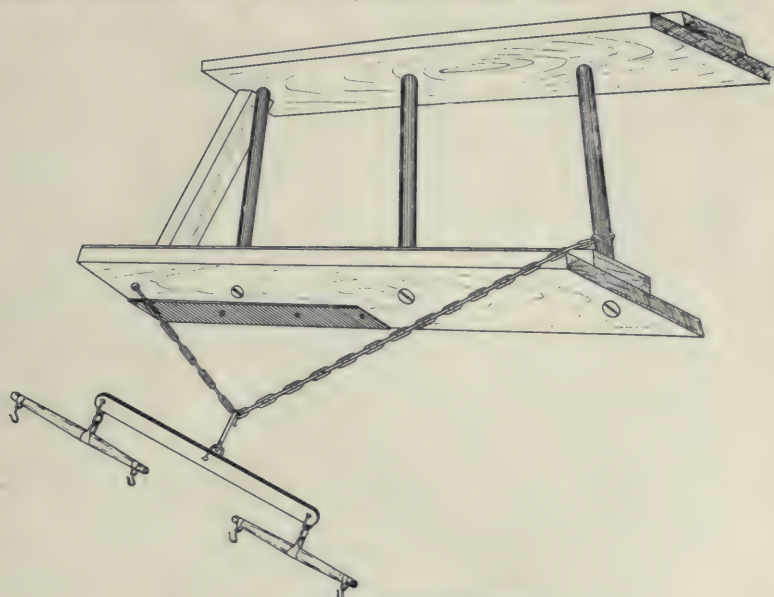


Fig. 15—Perspective View of Plank Drag.

Keep all depressions filled with same material as the surface is formed with.

When a depression forms in the surface of a road, if it is not filled, the pounding of traffic soon deepens and widens it, and a hole that might at first have been filled with a very small amount of material, if neglected, may require a yard or more. Gravel should be at hand in convenient piles for use in such cases. Do not attempt to fill a depression on a gravel road with any other material than gravel; nor attempt to fill a hole on an earth road with gravel. Use the same material for repairs as the surface is formed with, unless it is the intention to cover the whole surface for some distance with a more durable material.

Loosen material around depression before fill in.

Before filling up a depression on a gravel or stone road surface, it will be well to loosen the material around the sides or edges of the hole with a pick; then tamp the material well in. This will ensure a better bond between the new and old material and prevent the former from being pushed out with the traffic before becoming compacted.



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